

Final Technical Report

for

**Heat Transfer and Thermal Stability Research for
Advanced Hydrocarbon Fuel Technologies**

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Kenneth DeWitt
Principal Investigator

Benjamin Stiegemeier
Senior Research Associate

Department of Mechanical, Industrial and Manufacturing Engineering
University of Toledo
Toledo, Ohio 43606

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**Heat Transfer and Thermal Stability Research for
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by

Dr. Kenneth DeWitt (Distinguished University Professor)

Mr. Benjamin Stiegemeier (Senior Research Associate)

The University of Toledo

In recent years there has been increased interest in the development of a new generation of high performance boost rocket engines. These efforts, which will represent a substantial advancement in boost engine technology over that developed for the Space Shuttle Main Engines in the early 1970s, are being pursued both at NASA and the United States Air Force. NASA, under its Space Launch Initiative's Next Generation Launch Technology Program, is investigating the feasibility of developing a highly reliable, long-life, liquid oxygen/kerosene (RP-1) rocket engine for launch vehicles.

One of the top technical risks to any engine program employing hydrocarbon fuels is the potential for fuel thermal stability and material compatibility problems to occur under the high-pressure, high-temperature conditions required for regenerative fuel cooling of the engine combustion chamber and nozzle. Decreased heat transfer due to carbon deposits forming on wetted fuel components, corrosion of materials common in engine construction (copper based alloys), and corrosion induced pressure drop increases have all been observed in laboratory tests simulating rocket engine cooling channels. To mitigate these risks, the knowledge of how these fuels behave in high temperature environments must be obtained. Currently, due to the complexity of the physical and chemical process occurring, the only way to accomplish this is empirically.

Heated tube testing is a well-established method of experimentally determining the thermal stability and heat transfer characteristics of hydrocarbon fuels. The popularity of this method stems from the low cost incurred in testing when compared to hot fire engine tests, the ability to have greater control over experimental conditions, and the accessibility of the test section, facilitating easy instrumentation. These benefits make heated tube testing the best alternative to hot fire engine testing for thermal stability and heat transfer research. This investigation used the Heated Tube Facility at the NASA Glenn Research Center to perform a thermal stability and heat transfer characterization of RP-1 in an environment simulating that of a high chamber pressure, regenerative cooled rocket engine.

The first step in the research was to investigate the carbon deposition process of previous heated tube experiments by performing scanning electron microscopic analysis in conjunction with energy dispersive spectroscopy on the tube sections. This analysis gave insight into the carbon deposition process and the effect that test conditions played in the formation of deleterious coke. Furthermore, several different formations were observed and noted. One other crucial finding of this investigation was that in sulfur containing hydrocarbon fuels, the interaction of the sulfur components with copper based wall materials presented a significant corrosion problem. This problem in many cases was more life limiting than those posed by the carbon deposition process. The results of this microscopic analysis was detailed and presented at the December 2003 JANNAF Air-Breathing Propulsion Meeting as a Materials Compatibility and Thermal Stability Analysis of common Hydrocarbon Fuels (reference 1).

Using the results of the microscopic tube section analysis, work was started on re-writing the military specification for the rocket propellant RP-1 to support the RS-84 rocket engine project under NASA's Strategic Launch Initiative. Heated tube testing parametrically investigating the effect that sulfur content, time, and tube wall material play in the overall thermal stability and materials compatibility of RP-1 was performed. In these tests, the effect of reducing the overall sulfur content of the fuel was seen to dramatically improve the overall thermal stability of the fuel and almost entirely prevent the corrosion problems that were observed in past experiments. Furthermore, this test matrix included some limited testing with the new copper based alloy GRCo-84. The results of these tests were the first reported thermal stability testing done with this new material that has been developed specifically for rocket thrust chamber applications. The data from these tests significantly expanded the existing thermal stability test database for high pressure rocket engine applications. The results of this study were summarized and presented at the May 2004 52nd JANNAF Propulsion Meeting in Las Vegas (reference 2).

References

1. "A Materials Compatibility and Thermal Stability Analysis of Common Hydrocarbon Fuels", Meyer, M.L. and Stiegemeier B.R., 27th JANNAF Air Breathing Propulsion Meeting, December 1st, Colorado Springs, CO.
2. "RP-1 Thermal Stability and Copper Based Materials Compatibility Study", Stiegemeier, B.R., Meyer, M.L., and Driscoll, E., 52nd JANNAF Propulsion Meeting, December 10th, Las Vegas, NV.